

Spatial disparities in the European agriculture: A regional analysis

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Spatial disparities in the European agriculture:

A regional analysis

Abstract

This paper examines the territorial imbalances in European agriculture during the period 1980-2001, by means of the information provided by various methodological instruments which allow us to overcome the drawbacks of conventional convergence analysis. The results obtained reveal that the regional distribution of productivity in the agricultural sector is characterized by the presence of positive spatial dependence. This fact implies that the European regions in close spatial proximity register similar levels of the variable under study, which highlights the relevance of geographical location in this context. The empirical evidence presented also shows that regional disparities have remained almost constant during the time interval considered. However, the increase in density around the European average explains the observed reduction in the degree of bipolarization, while intra-distribution mobility is relatively limited. Finally, the analysis carried out allows us to assess the role of variables such as country of origin, investment per worker in the agricultural sector, regional per capita income or the size of the agrifood industry, in explaining the dynamics of the distribution under analysis.

Key words: Agricultural productivity, regions, European Union.

JEL code: Q10, R11, R12.

1 Introduction

Recent years have seen the publication of a great a number of works using a variety of approaches to analyze territorial imbalances in per capita income or aggregate productivity within the European Union¹. Various factors contribute to the level of interest raised by this issue. Not least among them are the major developments that have taken place in economic growth theory over the last twenty years, coinciding with the advent of endogenous growth models during the eighties. Another is the need to reduce development gaps across the various European regions, an issue that inspired some of the basic principles upon which the Union was founded, especially since the signing of the Single Act and the Maastricht agreements. Indeed, one of the specific assumptions of the European integration program is that it will drive the growth of all Member States, and thereby lead to economic and social cohesion².

However, sectoral analyses at regional level for the European Union as a whole are fewer in number³, probably as a result of problems arising from the scarcity of adequate statistical data. It is particularly striking to note that, to date, there has been very little in-depth analysis of regional disparities in European agriculture⁴. This is all the more surprising in view of the large amount of funds that have been allocated to the Common Agricultural Policy over the last four decades (Fennell, 1997; Ackrill, 2000)⁵.

¹A review of the main conclusions reported in this literature can be found in Armstrong (2002) or Terrasi (2002).

²Article 2 of the Treaty of the European Union specifically states that: “the Community mission will be to promote (...) the harmonious, balanced and sustainable development of economic activities, sustained growth (...), a high degree of convergence of economic performance (...)”.

³In relation to this, see Paci (1997), Paci and Pigliaru (1999) or Gil, Pascual and Rapún (2002).

⁴The only exception, to our knowledge, is the work by Colino and Noguera (2002). There are, however, several examples of research efforts using national level data to investigate this issue within the European setting, among which we could mention Schimmelpfennig and Thirtle (1999), Gutierrez (2000), Ball *et al.* (2001) or Aldaz and Millán (2003).

⁵This policy, the ultimate aim of which was to increase productivity in European agriculture, in line with the provisions of the Treaty of Rome, used 46.5 per cent of the Community budget in 2002.

In light of these circumstances, this paper aims to perform a fairly detailed analysis of the regional distribution of agricultural productivity in the European Union. Our ultimate goal, in doing so, is to draw some kind of inference that might be applied in the design of Community policy within the framework of the recent enlargement of the Union toward Central and Eastern Europe.

The few existing studies of regional disparities at sectoral level in the European context apply the concepts of sigma convergence and beta convergence introduced by Barro and Sala-i-Martin (1991, 1992), combining the information provided by various dispersion statistics with the estimation of convergence equations. However, as Quah (1993, 1996a,b; 1997) has repeatedly pointed out, not only does this approach raise a number of econometric problems, it also fails to capture a series of potentially interesting issues relating to the dynamics of the distribution in question. In particular, this type of analysis provides only a partial view of the observed distribution, since it neglects to consider, for example, the fact that the various regions may shift their relative positions over the study period; thus it completely ignores the possibility of intra-distribution mobility. The standard convergence approach also ignores the fact that a reduction in dispersion in the distribution under consideration may be compatible with a process of polarization into several internally homogeneous regional clusters (Esteban and Ray, 1994).

In order to overcome the limitations of conventional convergence analysis, we have opted in this paper to use the non-parametric approach proposed by Quah (1996a,b; 1997) to examine the dynamics of a distribution over time. In addition, we have applied a set of techniques adopted from spatial econometrics in order to examine the role played by the spatial dimension in this context.

The paper is based on data drawn from the Cambridge Econometrics regional database. Specifically, the agricultural productivity of 194 NUTS-2 regions for the period 1980-2001 has been calculated from data on gross value added at market prices and agricultural employment figures⁶. The data provided by Cambridge Econometrics are based mainly on the information supplied by Eurostat. Eurostat information on the agricultural sector, however, is seriously lacking in some respects, especially when it comes to data relating to the early 1980s (Shucksmith, Thomson and Roberts, 2005). For this reason, Cambridge Econometrics has opted to complete Eurostat data with alternative national statistics⁷.

The content of the paper is organized as follows. Following on from this introduction, section 2 presents an exploratory analysis of the spatial distribution of productivity in the agricultural sector in the European Union. Section 3 examines the evolution of regional disparities in gross value added per worker per worker in European agriculture between 1980 and 2001. Then, in section 4, we explore the dynamics of the distribution that concerns us, paying particular attention to polarization and regional mobility. This done, and in order to complete the results obtained, in section 5 we investigate the role played by a range of variables in explaining existing territorial imbalances in the European farming sector. We finish by presenting the main conclusions in section 6.

⁶NUTS is the French acronym for ‘Nomenclature of Territorial Units for Statistics’, a hierarchical classification of subnational spatial units established by Eurostat. In this classification, NUTS-0 corresponds to country level and increasing numbers indicate increasing levels of subnational disaggregation.

⁷In any event, lack of information for the whole of the time interval considered has obliged us to omit from our analysis the countries newly incorporated into the European Union in May 2004, as well as the former East German *Länder* and the French Overseas departments. We also decided not to include data for Brussels or Inner London, two regions with practically negligible levels of agricultural sector employment, but which, nevertheless, over time, register major fluctuations in the variable of interest, thus affecting the interpretation of our results.

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2 The regional distribution of agricultural productivity: An exploratory spatial data analysis

We will commence our study by carrying out an analysis of the spatial distribution of agricultural productivity in the European Union at the beginning and at the end of the time interval considered. To do so, and in order to avoid the possible influence of fluctuations in agricultural gross value added, due to climatic factors, for example, we have calculated the average productivity of the various regions between 1980 and 1983, and between 1998 and 2001 (four year averages). As can be observed, Figures 1 and 2 both reveal the presence of an apparent spatial non-stationarity in the distribution that concerns us. Indeed the presence of some degree of spatial heterogeneity and spatial dependence in this context is quite evident. Thus, notwithstanding the changes that have taken place over time, the regions with the highest levels of gross value added per worker in the agricultural sector are mainly those of the northern and central areas of the Union, while the lowest values, save for a few exceptions, are to be found in regions situated in the southern periphery. This spatial distribution to some extent matches the pattern of regional specialization. That is, the northern and central regions of Europe tend to be oriented towards animal farming, with a relatively large share of cereal and forage crops. The southern regions, meanwhile, concentrate more on the production of vegetables, especially permanent crops such as (fruits and vegetables, vines and olive groves) horticultural crops (DG Regio, 2001). In any event, it is worth mentioning that the pattern depicted in Figures 1 and 2 is consistent with the dualized view of European agriculture reported by, among others, Kearney (1992) and Gutierrez (2000).

This initial analysis, therefore, suggests that agricultural productivity is not ran-

domly distributed across the European space. By contrast, there appears to be positive spatial association between adjacent areas, in so far as neighboring regions tend to register similar levels of gross value added per worker in the agricultural sector. It is necessary to exercise caution when interpreting the information supplied by Figures 1 and 2, however, because any conclusion drawn from them will be highly sensitive to the number of intervals selected to represent the variable in question. It is therefore advisable to complete these initial results with the information obtained by means of Exploratory Spatial Data Analysis techniques (Anselin, 1998). This will allow us to gain a deeper understanding of the characteristics of the distribution under consideration, and check for the possible presence of different patterns of spatial association and spatial heterogeneity (Haining, 1990; Bailey and Gatrell, 1995).

[INSERT FIGURE 1 AROUND HERE]

[INSERT FIGURE 2 AROUND HERE]

Following this approach, we began by checking formally for the presence of spatial autocorrelation in the regional distribution of productivity in agricultural sector in the European Union. In this respect, it is worth mentioning that spatial autocorrelation can be defined as the coincidence of value similarity with locational similarity (Anselin, 2001). In order to study this issue, we calculated for each year of the study period the Moran's I global test, which can be written as follows (Cliff and Ord, 1973, 1981; Haining, 1990):

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{S_0 \sum_{i=1}^n (y_i - \bar{y})^2} \quad (1)$$

where y_i denotes the agricultural productivity in region i , while \bar{y} is the sample average. Likewise, w_{ij} denotes the corresponding element of the spatial weight matrix, W , with $\sum_{i=1}^n \sum_{j=1}^n w_{ij} = S_0$. As far as interpretation is concerned, it should be noted that after standardization, a significant and positive value of Moran's I will indicate the presence of positive spatial autocorrelation, while a significant and negative value of the statistic will indicate the existence of a pattern of spatial association between dissimilar values.

As can be seen from (1), before performing this test, it is first necessary to construct a spatial weight matrix to capture the strength of spatial interdependence between each pair of regions i and j . To do so, a first option is to use the concept of first order contiguity, according to which $w_{ij} = 1$ if regions i and j are physically adjacent and 0 otherwise⁸. However, the use of this type of matrix may raise problems in the European context, where the presence of islands means that W will include rows and columns containing only zeros. This implies that the observations in question are not considered in the analysis, which in turn has an effect on the interpretation of the results obtained. For this reason, in this paper we opted to use a spatial weight matrix that takes into account interactions beyond adjacent regions. In particular, following the proposal made by Le Gallo and Ertur (2003), we have considered a row-standardized matrix W based on the ten nearest neighbors, calculated using the geographical distance between the corresponding regional centroids (Pace and Barry, 1997; Pinkse and Slade, 1998)⁹.

Table 1 displays the results of the Moran's I global test of agricultural productivity for the 194 European regions of the sample over the 1980-2001 period. As can be

⁸This is in fact the option taken, for example, by López-Bazo *et al.* (1999) or Rey and Montouri (1999).

⁹In order to check the robustness of the conclusions obtained, we considered various spatial weight matrices. In particular, we constructed two more matrices W based on the fifteen and twenty nearest neighbours. Nevertheless, the results are in all cases very similar to those reported in the text.

checked, the values of the statistic are in all cases positive and statistically significant with $p = 0.0001$. This reveals the presence of a clear pattern of positive spatial association, which in turn supports the first impression drawn from observation of Figures 1 and 2 and supports the decision to apply spatial econometric techniques in this context¹⁰. We are able to conclude, therefore, that, within the European Union, spatially adjacent regions tend to be characterized by similar levels of agricultural productivity¹¹. This is only to be expected, bearing in mind that physically adjacent regions tend to be similar in climate and geography and also, therefore, in their agricultural production structure. It must not be overlooked, however, that efficiency in resource use varies across different agricultural activities, giving rise to productivity disparities among regions with different patterns of specialization (Helfand and Levine, 2004). Likewise, the existence of spatial autocorrelation would also be consistent with the results obtained for several geographical settings in a series of studies that highlight the presence of important R&D spillover effects in the agricultural sector (Johnson and Evenson, 1999; Schimmelpfennig and Thirtle, 1999; McCunn and Huffman, 2000). In any event, it is worth noting that Table 1 suggests that spatial factors have decreased in importance in the European setting over the course of the twenty-two years considered in our study.

¹⁰In fact, this result would be of particular importance if, following the approach adopted by Paci (1997), Colino and Noguera (2002) or Gil, Pascual and Rapún (2002), the aim of the analysis were to examine regional disparities in European agriculture through the estimation of convergence equations. Indeed, the information supplied by Table 1 raises serious doubts as to the consistency, unbiasedness and/or efficiency of estimations obtained without taking into account the existence of spatial dependence. A more detailed analysis of this issue can be found in Anselin (1988).

¹¹To further confirm this finding, we also constructed the Moran's scatterplots for the distribution under analysis. This is a graph on which the standardized values of the variable to be analyzed are plotted on the horizontal axis and the spatial lag of the same variable on the vertical axis. Thus each of the quadrants represents a different type of spatial association. According to Figures A1 and A2 which appear in the Appendix there is a noticeable concentration of regions in quadrants I and III, both at the beginning and end of the study period, thus confirming a predominating tendency in European agriculture toward spatial clustering involving regions with similar values of farm productivity, while there are relatively few cases of major disparity between the agricultural productivity of any given region and the average of its neighbors.

[INSERT TABLE 1 AROUND HERE]

It is important to keep in mind, however, that Moran's I is calculated on a global basis for the entire sample. Hence, we do not know whether, irrespective of the overall dependence pattern, there exist clusters of regions in which the concentration of high or low agricultural productivity levels is significantly greater than would be predicted in a spatially homogeneous distribution. In addition, it is not possible with these tests to detect the existence of groups of regions with dissimilar values of the study variable, that is, areas in which gross value added per worker in the agricultural sector is significantly lower or higher than in the adjacent areas. To overcome both these shortcomings, we calculated the local Moran's I, I_i , by means of the following expression (Anselin, 1995):

$$I_i = \frac{n(y_i - \bar{y})}{\sum_{i=1}^n (y_i - \bar{y})^2} \sum_{j \in J_i} w_{ij}(y_j - \bar{y}) \quad (2)$$

where J_i denotes the set of neighboring regions of i ¹². After standardization, a significant positive (negative) value of I_i will indicate clustering around region i of regions with similar (dissimilar) values of the study variable.

It is worth mentioning that the usual practice in the case of I_i is to assume a normal asymptotic distribution. Anselin (1995), however, has shown that the first and second order moments used in the standardization of the statistic I_i are obtained under the null hypothesis of no global spatial autocorrelation. For this reason, and following the proposal of this author, in this paper we calculated the pseudo-significance levels obtained by means of an empirical distribution derived from 10,000 random permutations.

¹²Note that $I = \frac{\sum_{i=1}^n I_i}{S_0}$, given that $\sum_{i=1}^n I_i = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^n (y_i - \bar{y})^2}$.

Figures 3 and 4 show the significant regional clusterings detected at the beginning and end of the study period, and indicate furthermore, whether or not they concentrate similar levels of agricultural productivity. In addition, Figures A3 and A4 in the Appendix, meanwhile, report the significance level corresponding to each region. As can be checked, the conclusions that emerge from the analysis carried out are consistent with the results obtained earlier. Thus, it is worth noting that, at the beginning of the time interval considered, the clusters of regions with high values of agricultural productivity are situated in Finland, the Netherlands, Belgium, northern France, central and southern regions of the United Kingdom. By contrast, the regional groupings characterized by low levels of agricultural productivity are located in Portugal, most of Spain and Austria, and the southern parts of Germany and Italy. The situation at the end of the sample period is similar to that just described. However, in 1998-2001 the I_i statistic for the Netherlands and various regions of Spain, Austria and southern Germany ceases to be statistically significant. Nevertheless, it must be borne in mind that at the end of the study period there emerge two new regional clusters. The first of these is made up of various Swedish regions with high agricultural productivity surrounded by other regions with high values of the study variable, while the second cluster is formed by the whole of Greece, grouping in this case regions with a lower level of gross value added per worker in the farm sector than those adjacent to them.

[INSERT FIGURE 3 AROUND HERE]

[INSERT FIGURE 4 AROUND HERE]

It is also worth mentioning the fact that the various regional clusters detected in the above analysis are comprised mainly by regions with similar levels of agricultural productivity. In any event, it is interesting to observe the slight increase that has taken place in the number of regions with significant and negative values of the local Moran's I statistic during the period 1980-2001. However, it must be borne in mind that, of the ten regions that in 1980-2001 presented a value of the variable of interest that was significantly distinct from that of their neighbors, only Luxembourg and Auvergne remain in the same situation at the end of the study period.

3 Regional disparities in the European agriculture

Following this preliminary analysis of the spatial distribution of the variable of interest, we continue our study by examining the evolution of regional disparities in gross value added per worker in the European Union agricultural sector. To this end, we consider the information supplied by the two dispersion measures commonly used to capture the concept of sigma convergence (Barro and Sala-i-Martin, 1991, 1992): the standard deviation of the logs (*SDlog*) and the coefficient of variation (*CV*)¹³.

First of all, it should be noted that the magnitude of the territorial imbalances observed in European agriculture is considerable greater than in the secondary and tertiary sectors (Table 2)¹⁴. In any case, as Figure 5 shows, inequality in the regional distribution of agricultural productivity within the European setting registered few relevant changes

¹³Dalgaard and Vastrup (2001) have demonstrated that the joint use of the standard deviation of the logs and the coefficient of variation does not prove redundant in this setting, since these two dispersion statistics could yield different conclusions.

¹⁴A similar result is found by Paci (1997) in a more limited geographical and temporal setting than that covered in the present study. Indeed, similar conclusions have been reached in national analyses. For the Spanish case, see, for example, Mas *et al.* (1994), Raymond and García-Greciano (1994) or Salinas-Jiménez (2003).

between 1980 and 2001. In fact, the variation in the values of *SDlog* and *CV* did not exceed 2 per cent during the whole of the twenty-two years contemplated. However, the degree of dispersion in the distribution that concerns us did not remain constant throughout that period. In fact, it is possible to identify three distinct stages, each with its own distinguishing features. Thus, during the eighties there was an increase in inequality, reaching its maximum level in 1990. However, in the early 1990s it is possible to detect a process of productivity convergence in European regional agriculture. This situation changes in 1997, when inequality again starts to increase.

[INSERT TABLE 2 AROUND HERE]

[INSERT FIGURE 5 AROUND HERE]

When assessing the implications of these findings, it is important to bear in mind that there exist various possible explanations for the lack of convergence in gross value added per worker in European agriculture throughout the entire period of analysis. Thus, it should be remembered that, in spite of the major structural reform that has taken place in the farm sector over the last few decades, agricultural productivity continues to be closely linked to the natural setting and climatic conditions of the various regions. This, in turn, helps to account for the heterogeneity of farming systems and the differences in their remunerative capacity, which constitute a considerable hindrance when it comes to reducing regional inequality over time (Jollivet and Eizner, 1996; Limouzin, 1996).

Having reached this point, we might naturally ask how much impact the Common Agricultural Policy (CAP) has had on regional disparities in European agriculture. Such

an analysis is far from easy, however (Shucksmith, Thomson and Roberts,2005), mainly due to the lack of available data for the level of territorial disaggregation and the time horizon considered in our study. Despite this limitation, however, it is worth pointing out that during the 1980s the European agricultural support system was fundamentally based on the implementation of agricultural support prices which are regulated by various common market organizations (Fennell, 1997; Ackrill, 2000). In fact, in 1985, the budget of the European Agricultural Guidance and Guarantee Fund (EAGGF) stood at 19,843.4 million Ecus, which was 71 per cent of the total EU budget. That same year, the highest level of support went to dairy products, which took up 30 per cent of EAGGF expenditure, followed by beef production (14 per cent), cereals (12 per cent), sugar (9 per cent) and oil-seed crops (6 per cent). The production of all of these products takes place mainly in the northern and central regions of the Union, in countries such as France, Germany, the Netherlands, the United Kingdom and Denmark. The Mediterranean produce of the southern regions, such as fruits, horticultural products, wine and olive oil, meanwhile, jointly received only 14 per cent of EAGGF expenditure(Commission of the European Communities, 1988). Thus, prices in the northern and central regions of the Union, which specialize in the most heavily subsidized products, have been higher than they would have been without such intervention, and their levels of gross value added and productivity have benefited as a result. Thus,it could be argued that the CAP may have contributed to agricultural productivity disparities among the European regions, in so much as Community intervention has tended to benefit the more productive areas of the Union, to the detriment of regions with lower values of this variable.

Since the CAP reform of 1992, support for agriculture has taken the form of direct farm payments. In theory, these payments are intended to be neutral in distributive

terms, since they are meant as compensation for loss of income resulting from the drop in intervention prices resulting from the reform. In 1996, with the reform complete, the EAGGF budget stood at 39,107.8 million Ecus, which was 49 per cent of the overall budget of the EU. The highest amounts that year went to herbaceous crops (cereals, rice, oil-seed and protein crops, which absorbed 42 per cent of EAGGF spending; sugar (4 per cent); dairy products (9 per cent); and beef (17 per cent). Together, these continental products concentrated 73 per cent of EAGGF spending. Mediterranean products (fruits, horticultural products, wine and olive oil), meanwhile, received 11 per cent (European Commission, 1998). These figures are a reflection of how the imbalance in CAP aid for these two groups of products has deepened over the years. The related empirical evidence presented by Shucksmith, Thomson and Roberts (2005) shows that CAP aid is spatially concentrated in the central and northern regions of the EU. Indeed, by the end of our period of analysis, the CAP could be said to be having an even more negative effect on agricultural productivity in the European regions than it was during the 1980s. In their assessment, Altomonte and Nava (2005) insist once more on the unfairness of the CAP at the farm level, since, in the year 2000, 50 per cent of the direct payments went to 5 per cent of the farms.

Leaving all other considerations aside, however, these remarks are still to be taken with a degree of caution. It is important to bear in mind that these figures do not allow us to establish a direct relationship between the evolution of the CAP over time and the trend in regional disparities in European agriculture as shown in Figure 5.

It should not be overlooked, moreover, that the evolutionary pattern of agricultural productivity is ultimately a consequence of changes in gross value added and/or employment in the different regions. Following the approach adopted by several authors

within the framework of the literature on territorial imbalances in per capita income, to explore the role of each of these variables in the evolution of regional disparities in European agriculture, a first option is to characterize the spatial distribution of gross value added and employment by applying some concentration measure (Villaverde, 2003). For obvious reasons, however, it is risky to relate the results of an analysis of this nature to the evolution of regional disparities in gross value added per worker in the agricultural sector. For a better understanding of this idea, let us consider a hypothetical situation in which two regions, each with a very different level of gross value added, exchange their respective employment levels. In such a context, none of the concentration measures proposed in the literature will register any variation over time, despite the obvious fact that changes in the spatial distribution of employment have an effect on observed inequality.

To overcome this problem, therefore, we perform an alternative analysis, in which we estimate the degree of dispersion in two virtual distributions. In the first, regional gross value added is kept constant at the level for the start of the period and only employment levels are allowed to vary. On the contrary, in the second virtual distribution employment is kept constant and only regional gross value added is allowed to vary over time. The results of this exercise are reported in Figure 6, where it can be checked that dispersion in the first virtual distribution remained practically constant throughout the period 1980 to 2001, while in the second it can be seen to increase. This shows that changes in the distribution of employment prevented an increase in regional disparities in the agricultural sector during the twenty-two years considered. Specifically, the empirical evidence provided in this respect suggests that the higher growth in gross value added registered by the regions located at the upper end of the distribution has in turn been

offset by a greater loss of employment in regions with low agricultural productivity levels in 1977. This conclusion is in fact consistent with the findings of Paci (1997) or Gil, Pascual and Rapún (2002) with respect to the process of structural change that has taken place in the European Union over the last few decades.

[INSERT FIGURE 6 AROUND HERE]

4 The dynamics of the regional distribution of productivity in the agricultural sector

In the section above we examined regional disparities in gross value added per worker in European agriculture. It is obvious, however, that the various dispersion measures calculated so far do not give a precise picture of the regional distribution of agricultural productivity in the European context (Quah, 1996a,b; 1997). For this reason, we will now estimate the density functions of the distribution analyzed. Following common practice in the literature, we will use non-parametric estimation techniques, thus avoiding the need to specify any particular functional form beforehand. This kind of approach undoubtedly offers major advantages in the present context, given the lack of generality and flexibility associated with parametric approximations.

Figure 7 shows the density functions of the regional distribution of gross value added per worker in the European agricultural sector estimated for various years of the study period. As is usual in the literature, in order to facilitate comparisons, normalized productivity levels are plotted on the horizontal axis (sample average equal to 100),

while the associated density estimates are plotted on the vertical axis¹⁵. According to Figure 7, the unimodality of the distribution analyzed is a constant throughout the time interval examined. Nevertheless, the results reveal certain differences in the shape of the estimated density during the twenty-two years considered, allowing us to conclude that the initial situation did not remain stable during the period. Thus, the density concentrated around the average increased between 1980-1983 and 1998-2001, largely due to weight loss at both ends of the distribution over the nineties. It is important to note that these results allow us to complete the findings obtained earlier in relation to the evolution of regional inequality in agricultural productivity throughout the study period.

[INSERT FIGURE 7 AROUND HERE]

There is a major limitation to the non-parametric approach used in this section so far, however, since it does not permit us to obtain a precise quantification of the variations in the degree of polarization that have taken place over time. To address this problem, we applied the methodology proposed by Esteban and Ray (1994), along with the extension by Esteban, Gradín and Ray (1999).

According to Esteban and Ray (1994), it is possible to measure the degree of polarization of a distribution f partitioned into a number of groups exogenously determined by means of the following expression:

$$PER(f, \alpha, \rho) = \sum_{j=1}^m \sum_{k=1}^m p_j^{1+\alpha} p_k |\mu_j - \mu_k| \quad (3)$$

¹⁵All estimates were based on Gaussian kernel functions, while the smoothing parameter was determined in each case following Silverman (1986, p. 47). It is worth mentioning that the results obtained are robust to the kernel function used.

where, for the purposes of the present study, μ_j and p_j denote, respectively, the average level of productivity in the agricultural sector and the population share of group j . Likewise, $\alpha \in [1, 1.6]$ is a parameter that captures the degree of sensitivity of *PER* to polarization. Nevertheless, before applying this measure, it is necessary to define a simplified representation of the original distribution in a series of exhaustive and mutually exclusive groups, $\rho = (z_0, z_1, \dots, z_m, \mu_1, \dots, \mu_m, p_1, \dots, p_m)$, the boundaries of which are given by intervals of the form $[z_{j-1}, z_j]$, for $j = 1, \dots, m$. This will involve some degree of error, however, as this grouping will generate some loss of information, depending on the degree of dispersion within each of the groups considered. Taking into account this idea, the measure of generalized polarization proposed by Esteban, Gradín and Ray (1999) is obtained after correcting the *PER* index applied to the simplified representation of the original distribution with a measure of the grouping error, $\varepsilon(f, \rho)$.

It is important to bear in mind, meanwhile, that there are no unanimous criteria for establishing the precise demarcation between the various groups. To address this problem, Esteban, Gradín and Ray (1999) use the methodology proposed by Aghevli and Mehran (1981) and Davies and Shorrocks (1989) in order to find the optimal partition of the original distribution, ρ^* . This means selecting the partition that minimizes the Gini index value attributable to within-group inequality, $G(f) - G(\rho^*)$ ¹⁶. The measure of generalized polarization proposed by Esteban, Gradín and Ray (1999), therefore, is given by:

$$PEGR(f, \alpha, \rho^*, \beta) = PER(f, \alpha, \rho^*) - \beta [G(f) - G(\rho^*)] \quad (4)$$

where $\beta \geq 0$ is a parameter that informs about the weight assigned to the error term in

¹⁶Note that in this case there is no overlapping between the various groups, since the decomposition of the Gini index into between-group and within-group inequality is exact (Pyatt, 1976).

expression (4).

We proceeded by applying this methodology to the study of the evolution of polarization in the regional distribution of agricultural productivity in the European Union for the two-group case (bipolarization). In order to check the robustness of the results of our analysis, we consider different values of the parameter of sensitivity to polarization. Specifically, $\alpha = 1, 1.3, 1.6$. Likewise, as in Esteban, Gradín and Ray (1999), $\beta = 1$ in all cases.

As shown in Figure 8, the results obtained reveal a reduction in generalized bipolarization over the period analyzed, which was particularly intense between 1985 and 1995. Indeed, the value of *PEGR* decreased by between 12 and 22 per cent, depending on the degree of sensitivity to polarization considered in each case¹⁷.

[INSERT FIGURE 8 AROUND HERE]

Nevertheless, expression (4) highlights the fact that the evolution of *PEGR* depends on two factors: the polarization observed in the simplified representation of the original distribution and the degree of internal dispersion within each of the various groups. Figure 9, therefore, provides additional information regarding these two components of the generalized polarization measure. Thus, it is possible to observe a decrease in bipolarization in the simplified representation during the time interval considered. Specifically, the value of *PER* fell by 4 per cent for the various levels of sensitivity to polarization considered in the analysis. With respect to the evolution of the error term, Figure 9

¹⁷The optimal partitioning for the two-group case is characterized by the fact that the productivity level that separates the two groups coincides with the sample average. By adopting this criterion for the classification of the various regions considered, it is possible to explain an average of 71 per cent of total inequality, measured in terms of the Gini index. Thus, the within-group inequality left unexplained by this partition is about 29 per cent.

reveals that the degree of internal cohesion in both groups decreased, since the value of ε increased by 8 per cent throughout the twenty-two years contemplated. In any event, this evolution of the error term contributes to explain the reduction in generalized bipolarization observed between 1980 and 2001, since the level of bipolarization predicted in the simplified representation of the original distribution worsens in absolute terms.

[INSERT FIGURE 9 AROUND HERE]

The analysis carried out so far is based exclusively on the information obtained from a series of cross-sectional observations of the distribution under study. Therefore, it does not take into account that, over time, the different economies may modify their relative positions in terms of agricultural gross value added per worker (see Mora (2004) or Ezcurra, Pascual and Rapún (2006) for further details about the importance of this issue). To address this shortcoming and to complete the results obtained so far, we examined the degree of mobility in the regional distribution of agricultural productivity within the European Union during the period 1980-2001.

Most of the studies that have addressed this issue are based on the information provided by discrete transition matrices, obtained by dividing the distribution into a series of exhaustive and mutually exclusive classes¹⁸. This approach entails a problem, however, since the results it yields are sensitive to the discretization used to define the various classes (Bulli, 2001; Kremer, Onatski and Stock, 2001). To address this problem, Quah (1996a, 1997) suggests substituting the transition matrix with a stochastic kernel to reflect the probabilities of transition between a hypothetically infinite number of

¹⁸For example, for the European case López-Bazo *et al.* (1999) and Le Gallo (2004) estimate various transition matrices to analyze regional mobility in terms of per capita income and aggregate productivity.

classes, reducing their size infinitesimally (see Durlauf and Quah (1999) for a formal definition). The stochastic kernel can be reached by estimating the density function of the distribution over a given period, $t + k$, conditioned on the values corresponding to a previous period, t . In other words, the joint density function at moments t and $t + k$ is estimated and then divided by the implicit marginal distribution in order to obtain the corresponding conditional probabilities.

Figure 10 shows the stochastic kernel and the corresponding contour-plot estimated for five-year transitions (Fingleton and López-Bazo, 2003)¹⁹. The three-dimensional graph shows how the cross-sectional distribution at t evolves into that observed at $t + 5$. In fact, the stochastic kernel gives us the probability distribution of agricultural productivity at $t + 5$ for a region with a given value at t . Thus, if the probability mass is concentrated around the main diagonal, the intra-distribution dynamics are characterized by a high level of persistence in the relative positions of the regions over time and, therefore, low mobility. If, on the other hand, the density is located mainly on the diagonal opposite the main diagonal, this would indicate a switching of the relative positions of the regions situated at each end of the distribution. Finally, the probability mass could, in theory, accumulate parallel to the t axis. This would reflect the convergence of regional gross value added per worker in the agricultural sector throughout the study period around a certain value of productivity. In order to aid interpretation of the graph, Figure 10 also includes contour plots on which the lines connect points at the same height on the three-dimensional kernel.

[INSERT FIGURE 10 AROUND HERE]

¹⁹Gaussian kernel functions were used in all cases, while the smoothing parameter was selected following Silverman (1986, p. 86).

As can be observed, Figure 10 reveals that the probability mass is basically concentrated around the main diagonal. This illustrates the limited degree of mobility in the regional distribution of gross value added per worker in the agricultural sector over the study period. The European regions, therefore, tended on the whole to maintain their relative positions in this context over the twenty-two years contemplated. The bumps in the tails of the distribution shown in Figure 10 are worth noting, however, since they help to reveal the role played by the regions situated at the upper and lower ends of the distribution in explaining the above-mentioned reduction in polarization during the sample period²⁰.

We then estimated the corresponding ergodic distribution by iteration of the stochastic kernel to reach the convergence of the process (Johnson, 2000). Given that this is, by definition, a continuous distribution, it can be represented graphically (Figure 11). As shown, the ergodic distribution obtained is characterized by a single local maximum located around the sample average, which is, in turn, consistent with the information yielded by the density functions estimated in Figure 7 for various years of the period 1980-2001²¹. This indicates that the existing territorial imbalances in European agriculture will persist into the future. Nevertheless, it is interesting to note that there is no evidence to suggest that the long term outcome might be a fragmentation of the distribution under study into various separate groups of regions.

[INSERT FIGURE 11 AROUND HERE]

²⁰Though estimations were repeated for different transition periods, the results in all cases proved very similar to those just discussed. They are not reported here for lack of space, but are available from the authors upon request.

²¹Having reached this point, however, it should be noted that any comparison of Figures 7 and 11 must be based exclusively on the shape of the distributions, since there is no point in comparing the density levels that appear on the vertical axes.

5 Determinants of the dynamics of the regional distribution of agricultural productivity

In order to complete the results obtained so far, in this section we will examine the role played by a series of variables in the dynamics of the regional distribution of gross value added per worker in the European agricultural sector. We will tackle this issue using a series of instruments proposed by Quah (1996a, 1997) and already presented in the preceding pages. These will enable us to obtain a fairly accurate assessment of how far the distribution varies when factors relating to issues other than agricultural productivity are introduced into the analysis.

Ever since the pioneer work by Molle, Van Holst and Smit (1980), authors dealing with spatial disparities in per capita income or aggregate productivity within the European setting have placed repeated emphasis on the importance of country-specific factors in regional growth processes (Quah, 1996c; Rodríguez-Pose, 1999; Ezcurra *et al.*, 2005). It will be of interest, therefore, to explore the role played by the national component in the evolution of the regional distribution of gross value added per worker in European agriculture throughout the period considered. With this idea in mind, we constructed a conditioned distribution by normalizing each region's agricultural productivity according to the average in the rest of the country to which it belongs, excluding the region in question.

Leaving aside any political and administrative factors, we also considered the possible influence on the regional distribution of agricultural productivity of variables such as investment per worker in agriculture, regional per capita income, or the role of industries

directly related with farming activity²². For our purposes, we classified the various regions by deciles, taking as reference the average values of the different variables over the whole of the sample period. We then constructed three more conditioned distributions, this time normalizing each region's agricultural gross value added per worker according to the average agricultural productivity level of those regions in the same decile.

The various conditioned distributions just defined can be intuitively interpreted as that part of the original distribution that remains unexplained by the set of variables considered. For a better understanding of this idea, let us imagine a situation in which the “country effect” had no influence whatsoever on the evolution of the distribution under analysis, such that regions with a below (above) the sample average agricultural gross value added per worker would also be less (more) productive than the rest of the regions in the country to which they belong. In this hypothetical situation, the original distribution would coincide with the conditioned distribution. If, on the other hand, the national component were to play a relevant role, it would be reasonable to expect that productivity in the less (more) productive regions to be closer to the average of the group to which they belong, defined, this time, from a political-administrative point of view.

To overcome the problems involved in using discrete transition matrices in this context, we have opted in this paper to employ a non-parametric approach based on the estimation of stochastic kernels and contour plots²³. Before going on to discuss the outcomes obtained, it might be worth clarifying a few points relating to the interpretation

²²This last variable was proxied by the contribution to regional gross value added made by the food, beverages and tobacco industry (sectoral classification NACE-CLIO R17). It should be noted in this respect that, despite our best efforts, we were unable to obtain data at a higher level of sectoral disaggregation to cover the entire geographical and temporal scope of the present study.

²³This type of methodology has been used, for example, by Ezcurra, Gil and Pascual (2005) to investigate the causes of regional disparities in welfare in the European Union.

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of stochastic kernels and contour plots in this context. Within this framework, these instruments provide information concerning the probabilities of transition between the initial distribution and the conditioned distribution, and not between two moments of time as in the previous case. Thus, if the factors considered do not contribute to explain the distribution dynamics, the probability mass should cluster around the main diagonal. If, on the other hand, the variables selected are determinant in explaining the evolution of the distribution analyzed, the density will tend to accumulate parallel to the axis corresponding to the initial distribution and around the average.

[INSERT FIGURE 12 AROUND HERE]

[INSERT FIGURE 13 AROUND HERE]

[INSERT FIGURE 14 AROUND HERE]

[INSERT FIGURE 15 AROUND HERE]

Figures 12, 13, 14 and 15 present the results obtained when this methodology is used to examine the role of the country to which a region belongs, investment in the agricultural sector, regional per capita income, and the size of the agrifood sector, in explaining the dynamics of the regional distribution of gross value added per worker in the European agriculture. The empirical evidence provided by the various graphs clearly shows that, unlike the rest of the variables analyzed, the national component and investment per worker in agriculture play an important role in this context. Thus, the analysis carried out reveals considerable differences between the regional distribution

of agricultural productivity in any member State and in the European Union as a whole. Close observation of the graphs in Figure 12, however, allow us to qualify this finding, at least in part. The “country effect” does indeed appear to be more significant among regions with low or medium values of the variable analyzed. At the same time, however, the probability mass at the upper end of the distribution appears to be approaching the main diagonal. This suggests that agricultural productivity is closer to the national average in regions where gross value added per worker in agriculture is relatively low.

Figure 13, meanwhile, highlights the predominant role played by agricultural investment in this context. Unlike the national component, however, this variable proves more relevant in regions located at the upper end of the distribution that concerns us, given that, generally speaking, agricultural productivity in these regions tends to be on a par with that of other regions making a similar level of investment in the sector.

6 Conclusions

Throughout the preceding pages, we have examined territorial imbalances in European agriculture between 1980 and 2001. In order to overcome the limitations of conventional convergence analysis, in this paper we have combined the non-parametric approach proposed by Quah (1996a,b; 1997) with a set of techniques adopted from spatial econometrics.

The results obtained show the presence of positive spatial dependence in agricultural productivity. This reveals that, with a few specific exceptions, spatially adjacent regions in the European setting register similar values of the variable analyzed, which contributes to highlight the relevance of geographical location in this context. In particular, we have detected the existence of several clusters of regions with levels of gross value added per

worker in agriculture similar to each other but different from those of adjacent zones. These clusters are not randomly distributed across the whole of Europe, however. They are in fact located in specific areas of the North, Centre and South of the European Union. It should not be overlooked, in relation to this, that agricultural productivity is closely linked to the natural setting and climatic conditions of the various regions.

The level of spatial dispersion in agricultural productivity is also found to have remained practically constant between 1980 and 2001. This is due to the fact that the higher growth in gross value added registered by the regions at the upper end of the distribution was offset by a greater loss of employment in the less productive regions.

At the same time, the various density functions estimated show that the probability mass concentrated around the sample average increased over the course of the twenty-two years considered, largely due to loss of weight at both ends of the distribution that concerns us. As a consequence, regional bipolarization decreased during the time interval considered, irrespective of the value adopted in the analysis by the parameter of sensitivity to polarization.

We also examined the level of mobility in the distribution under study. The results obtained in this respect suggest a low degree of intra-distribution mobility. Therefore, save for a few exceptions, the European regions tend to have maintained their relative positions in terms of agricultural productivity between 1980 and 2001.

Finally, we explored the role played in the dynamics of the regional distribution of gross value added per worker in the sector considered by variables such as the country to which a region belongs, investment per worker in agriculture, regional per capita income, or the impact of industries directly related to agricultural activity. The empirical evidence provided in this respect reveals the importance in this context of the national

component and investment in agriculture. The analysis carried out shows, in particular, that agricultural productivity appears to be closer to the national average in regions with relatively low levels of the variable under study. Investment in agriculture, meanwhile, is more relevant at the upper end of the distribution, where regions with matching levels of investment in the agricultural sector also tend to share similar productivity levels.

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Appendix

[INSERT FIGURE A1 AROUND HERE]

[INSERT FIGURE A2 AROUND HERE]

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[INSERT FIGURE A4 AROUND HERE]

For Peer Review

Tables and Figures

Table 1: Moran's I statistics for the regional distribution of agricultural productivity.

Year	Moran's I	Mean	Standard deviation	Standardized value
1980	0.4628	-0.0050	0.0290	16.1085
1981	0.5462	-0.0050	0.0290	19.0294
1982	0.5758	-0.0050	0.0289	20.1274
1983	0.5740	-0.0050	0.0290	19.9376
1984	0.5760	-0.0050	0.0289	20.1043
1985	0.5563	-0.0050	0.0292	19.2484
1986	0.5781	-0.0050	0.0287	20.3454
1987	0.5833	-0.0050	0.0290	20.2974
1988	0.5469	-0.0050	0.0290	19.0557
1989	0.5203	-0.0050	0.0289	18.1998
1990	0.4596	-0.0050	0.0288	16.1091
1991	0.4180	-0.0050	0.0289	14.6513
1992	0.5029	-0.0050	0.0289	17.5649
1993	0.5076	-0.0050	0.0289	17.7592
1994	0.5034	-0.0050	0.0287	17.6949
1995	0.5223	-0.0050	0.0287	18.3618
1996	0.4800	-0.0050	0.0286	16.9641
1997	0.4401	-0.0050	0.0288	15.4520
1998	0.4153	-0.0050	0.0287	14.6361
1999	0.4112	-0.0050	0.0287	14.4754
2000	0.4161	-0.0050	0.0289	14.5588
2001	0.3671	-0.0050	0.0289	12.8605

Notes: Inference is based on the permutation approach with 10,000 permutations (Anselin, 1995).
All statistics calculated are significant at $p = 0.0001$.

Table 2: Regional disparities in the various sectors.

Sector	<i>SDlog</i>	<i>CV</i>
Agriculture	0.5403	0.4619
Industry	0.3796	0.4290
Services	0.2987	0.2846
Total	0.3281	0.3005

Note: Average for the period 1980-2001.

Figure 1: Spatial distribution of agricultural productivity, 1980-1983 (four year averages).

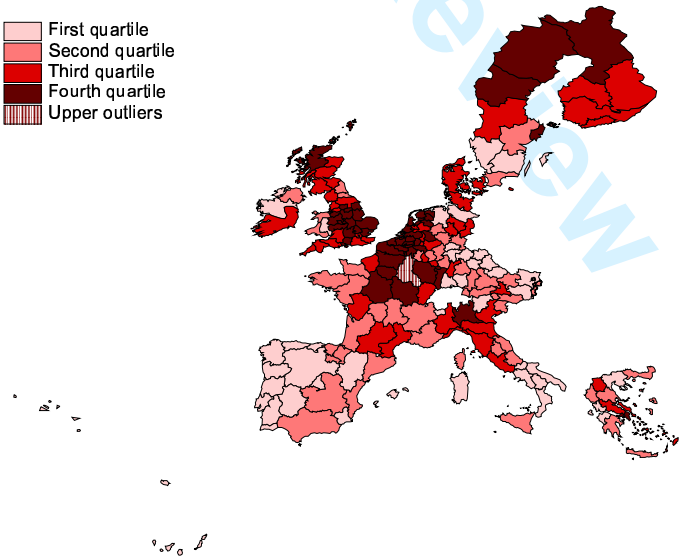


Figure 2: Spatial distribution of agricultural productivity, 1998-2001 (four year averages).

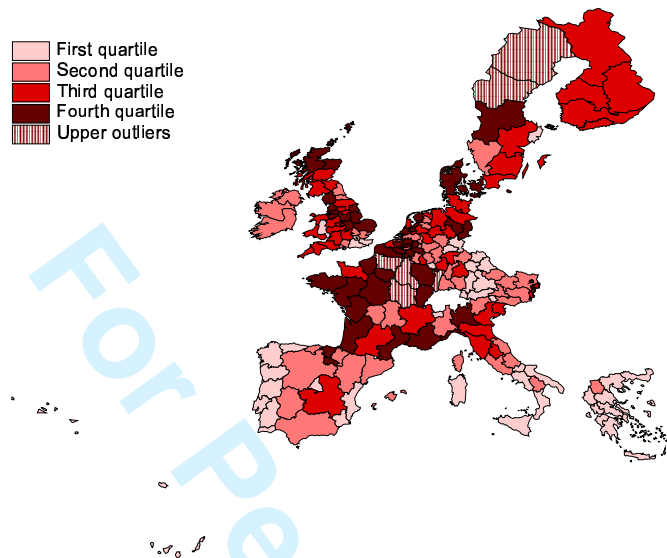


Figure 3: Spatial distribution of local Moran's I, 1980-1983 (four year averages).

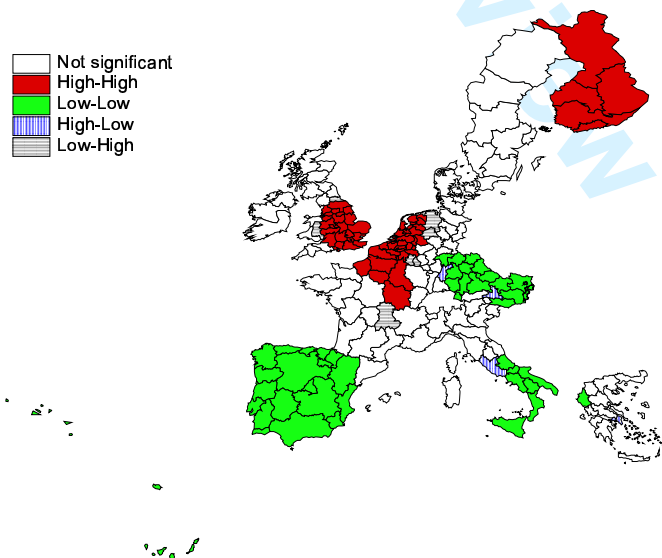


Figure 4: Spatial distribution of local Moran’s I, 1998-2001 (four year averages).

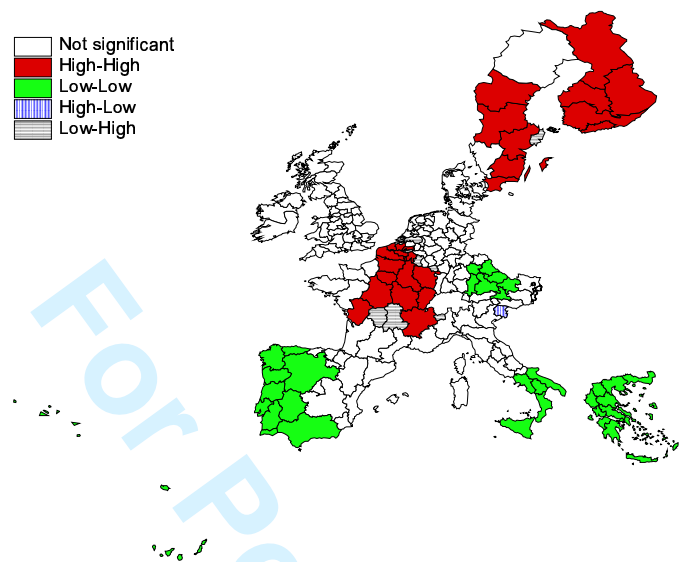


Figure 5: Regional disparities in agricultural sector productivity.

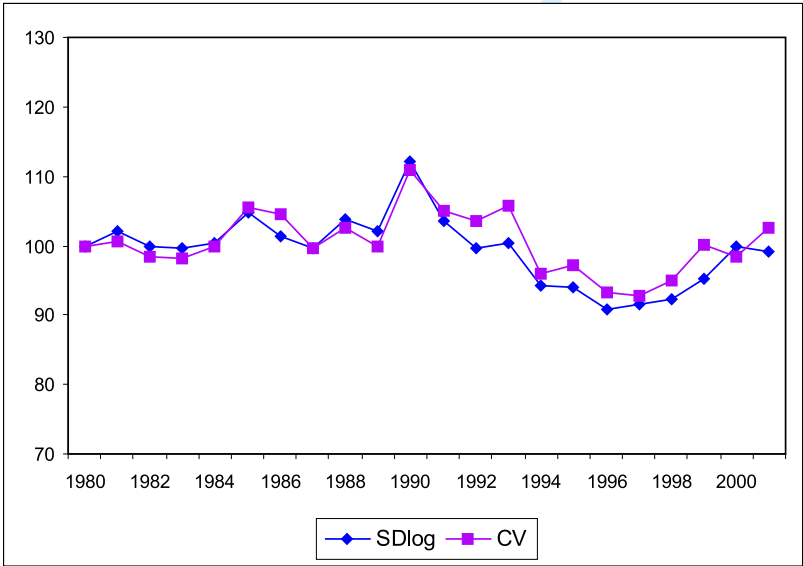


Figure 6: Regional disparities: the role of variations in gross value added and employment.

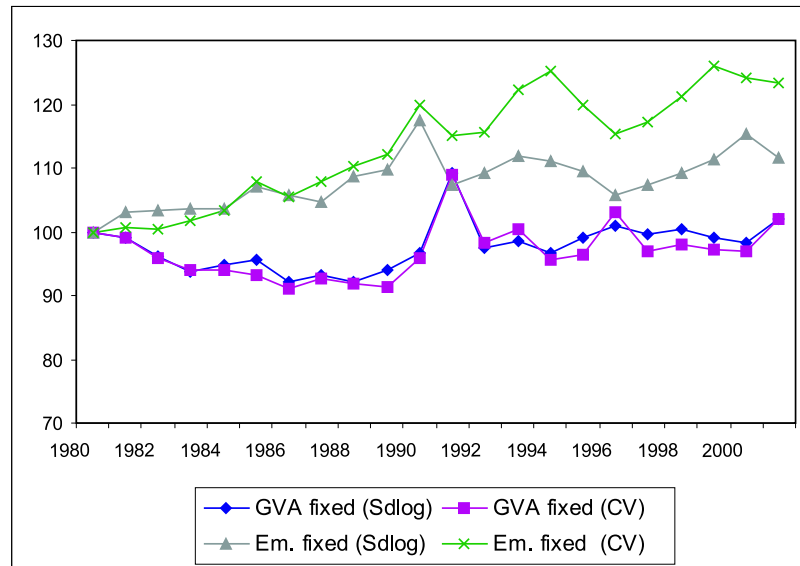


Figure 7: Density functions of the regional distribution of agricultural productivity.

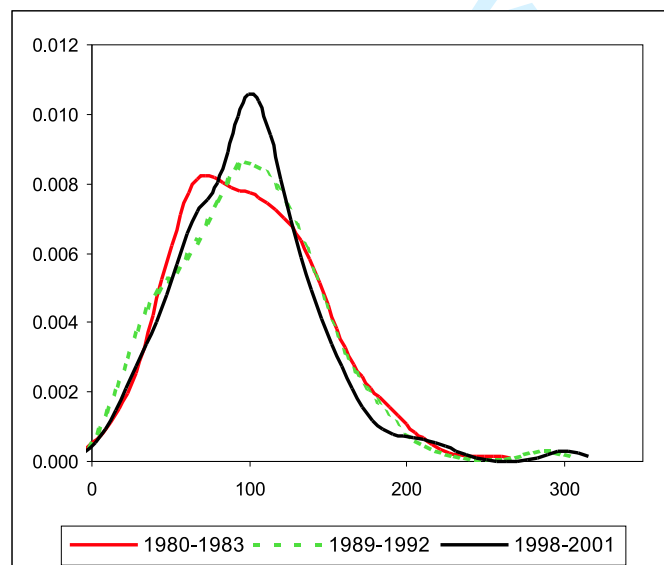


Figure 8: Generalized bipolarization.

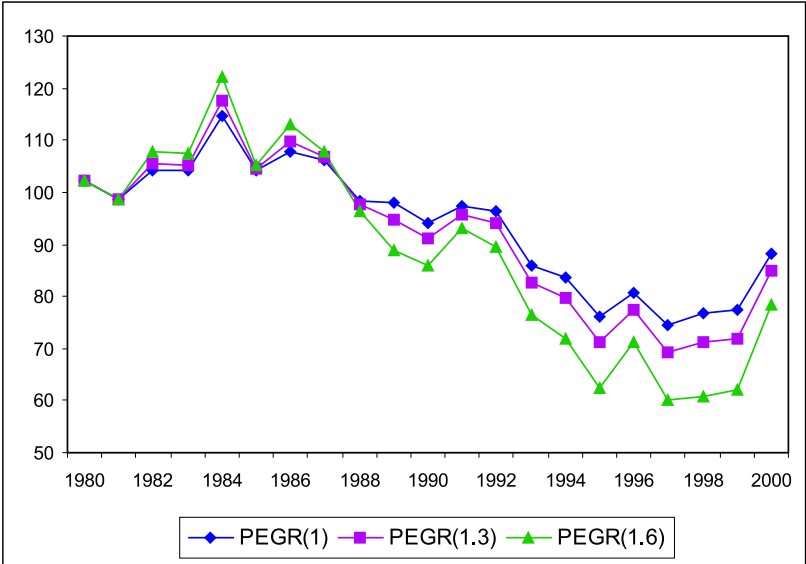


Figure 9: Bipolarization of the simplified representation and internal dispersion.

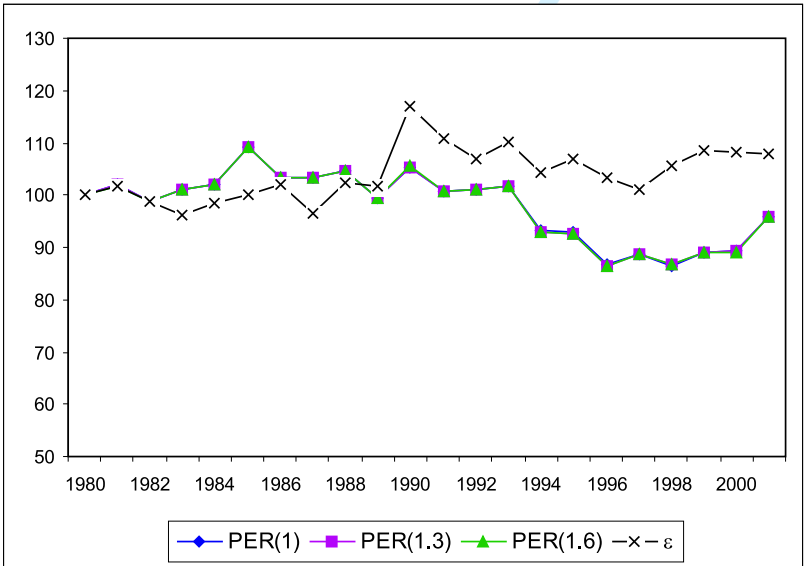


Figure 10: Stochastic kernel and contour plot of the regional distribution of agricultural productivity (five year transitions).

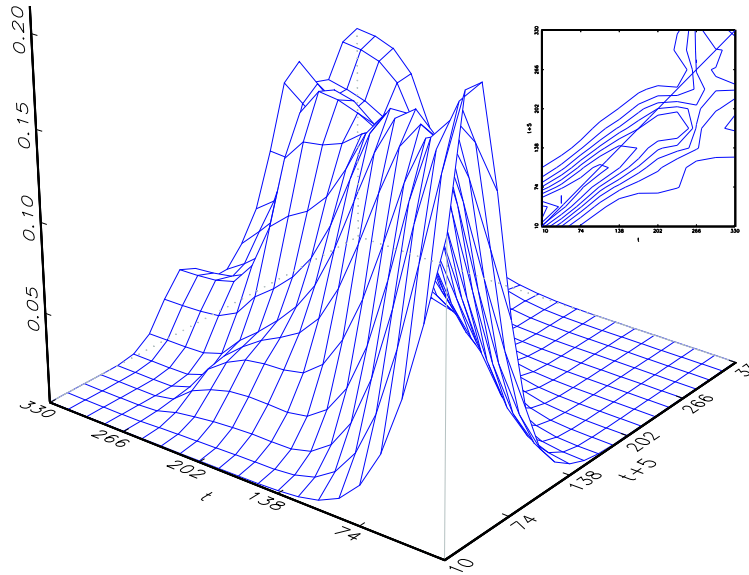


Figure 11: Ergodic distribution of regional agricultural productivity.

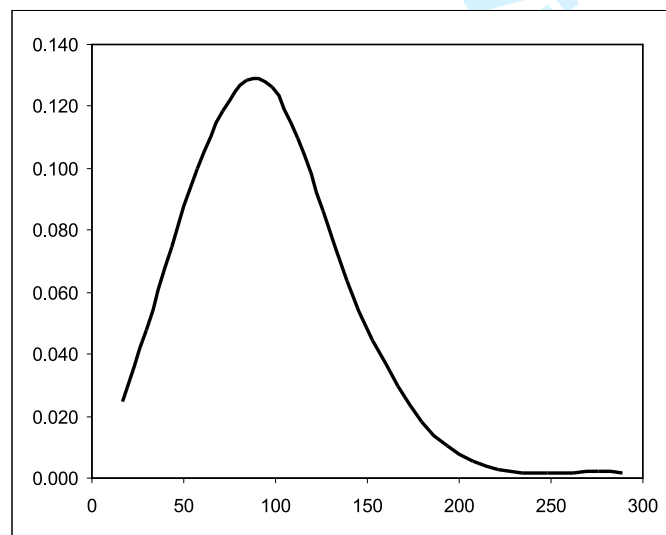


Figure 12: The national component and the dynamics of the regional distribution of agricultural productivity.

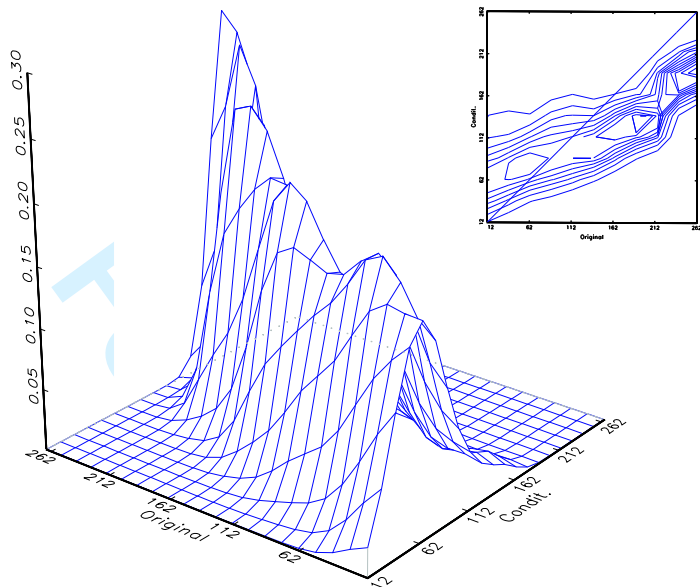


Figure 13: Investment per worker in the sector and the dynamics of the regional distribution of agricultural productivity.

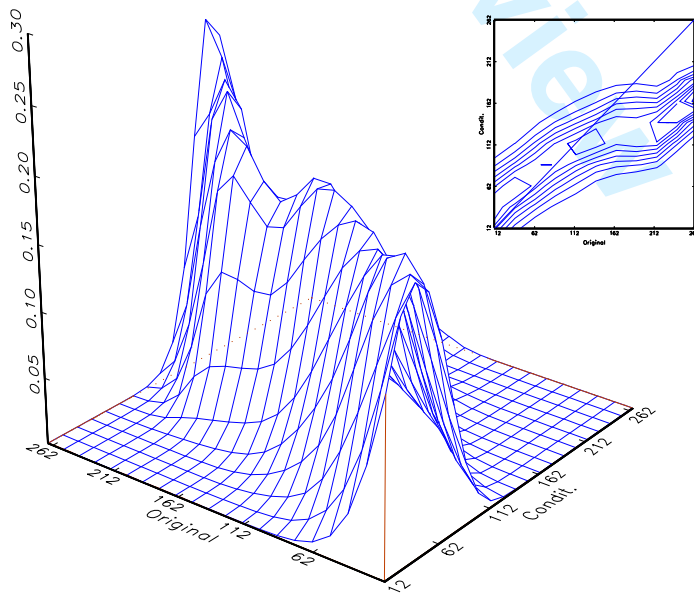


Figure 14: Development level and the dynamics of the regional distribution of agricultural productivity.

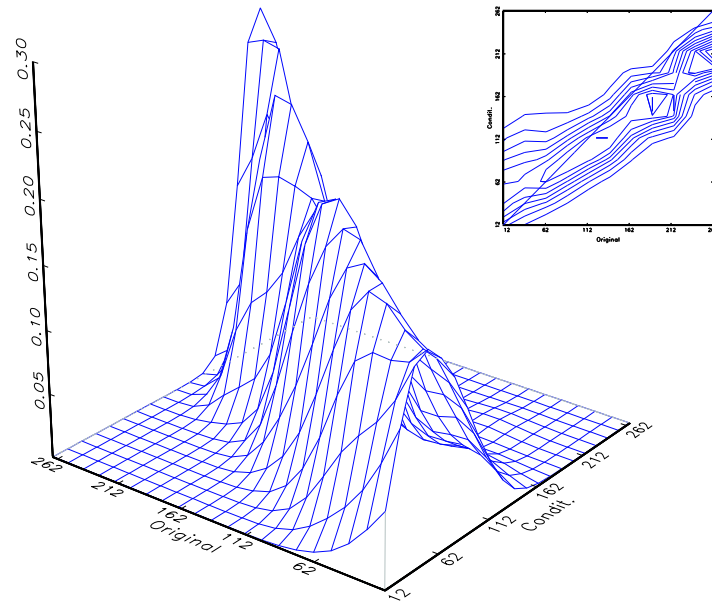


Figure 15: The agrifood industry and the dynamics of the regional distribution of agricultural productivity.

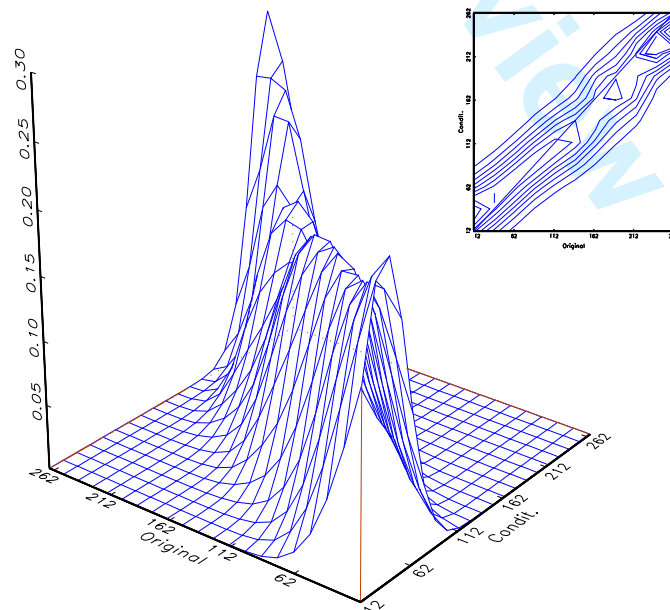


Figure A1: Moran’s scatterplot, 1980-1983 (four year averages).

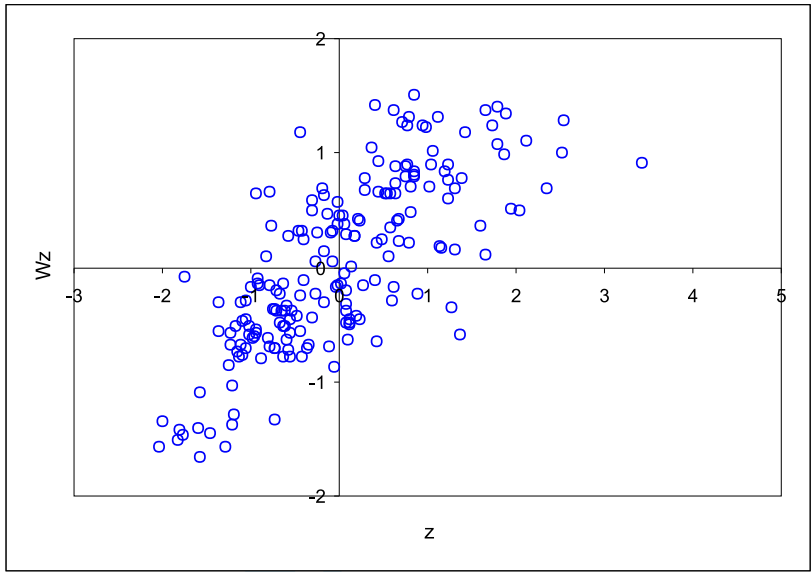


Figure A2: Moran's scatterplot, 1998-2001 (four year averages).

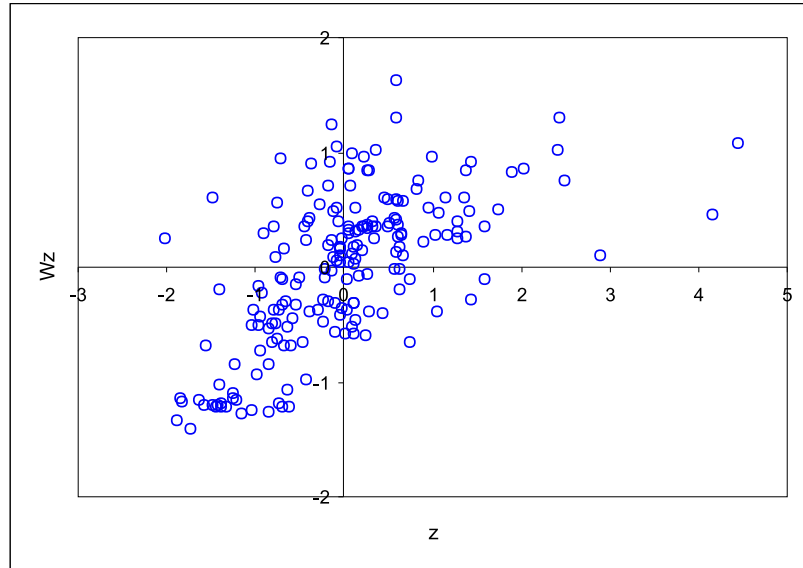
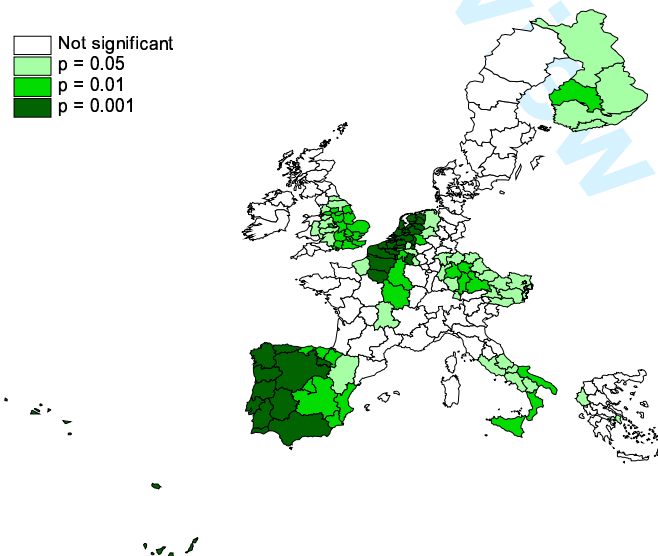


Figure A3: Significance of local Moran's I test, 1980-1983 (four year averages).



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Figure A4: Significance of local Moran’s I test, 1998-2001 (four year averages).

